RELATING TO FUEL INJECTION SYSTEMS

FIELD OF THE INVENTION

[0001] The present invention concerns improvements relating to fuel injection systems for internal combustion engines and provides, more specifically, a fuel injection system which is capable of providing a range of injection pressure, or injection rate, characteristics for a given injector. The invention also relates to a control method for such a fuel injection system.

BACKGROUND TO THE INVENTION

[0002] Within current fuel injection systems a pump is used to deliver fuel to the engine cylinders via a high pressure supply line and, in the course of an 'injection', fuel enters a cylinder through one or more apertures which otherwise remain closed by seated injection needles. Typically, a vehicle travelling at around 30 miles per hour, say, will require tens of injections to be made into each of its engine cylinders per second.

[0003] Research has shown that, for a given injector, significant improvements in combustion quality and efficiency are achieved by rapidly varying the injection pressure, or injection rate, within an injection event. More particularly, commencing the event with a pilot injection at lower pressure and then following that with a main injection at higher pressure (as shown in the example injection profile of **FIG. 1***a*), has highly beneficial effects on combustion emissions and noise. The benefits to emissions are still further improved if the main injection has a so-called 'boot-shaped' injection profile (an example of which is shown in **FIG. 1***b*), whereby the main injection commences at a pilot pressure P**1** but is then rapidly increased to a significantly higher pressure P**2**.

[0004] The timing of when fuel is supplied to an engine cylinder is determined by the movement of an injection valve needle of the associated injector. A known injector **200** is shown schematically in **FIG. 2***a*. An electronically operated three-way needle control valve **202** is provided for controlling movement of an injector valve needle **204**, relative to its seating **206**, thereby to control the delivery of fuel from a fuel delivery chamber **207** to the engine cylinder (the engine cylinder is not shown in **FIG. 2***a*). The needle control valve **202** is operable either to connect a high pressure (HP) supply line **208** and a control chamber **210** which houses the non-seating end of the valve needle **204**, or to connect the control chamber **210** with a low pressure (LP) reservoir. The high pressure supply line **208** also supplies the fuel delivery chamber **207** which houses the seating end of the valve needle **204**.

[0005] When the needle control valve **202** is in its 'closed' position (as shown in **FIG. 2***a*), the control chamber **210** communicates with the high pressure supply line **208** such that it floods with high pressure fuel. This fuel, together with a spring **212** located in the control chamber **210**, serves to urge the valve needle **204** against its seating **206** so that no fuel enters the cylinder. In contrast, when the needle control valve **202** is 'open' (as shown in **FIG. 2***b*), communication between the control chamber **210** and the high pressure supply line **208** ceases and the control chamber **210** communicates instead with the low pressure reservoir. The valve needle **204** experiences so-called thrust forces arising from the high pressure fuel surrounding it (as shown in **FIG. 3** prior to the needle **204** lifting). As pressure within the control chamber **210** reduces, these thrust forces become sufficient to overcome the force of the control chamber spring **212** and the valve needle **204** lifts from its seating **206**, whilst the injector **200** continues to be supplied by the high pressure supply line **208**. Accordingly, fuel is injected into the engine cylinder, through the revealed apertures, during an injection.

[0006] With regard to the desired boot injection profile, one way of increasing the pressure, or rate, at which fuel is injected for a given injector **200** is to use a pumping arrangement. Prior to engagement of the pumping action, a control valve is used to close communication with the high pressure fuel supply line **208**. A known fuel injection system **400** of this type, devised by the present applicant and described in WO 03/093671, will now briefly be described with reference to **FIG. 4**.

[0007] The fuel injection system **400** is comprised of a high pressure fuel supply means **402** including a fuel pump **408** and an accumulator volume **410** which stores fuel at a moderately high and injectable pressure (for example, 300 bar). The accumulator volume **410** is more commonly referred to as a 'common rail'. The high pressure fuel supply means **402** supplies fuel to a pumping arrangement **404** and the fuel injector **200** of the system, as described above, via a high pressure supply line **208**. In between the high pressure fuel supply **402** and the pumping arrangement **404**, the high pressure supply line **208** is provided with a supply control valve **406**. The supply control valve **406** and fuel injector **200** are both electronically operable and are controlled by an associated electronic engine controller (not shown) which controls operation of the supply control valve **406** and the action of the pumping arrangement **404** during injections.

[0008] The pumping arrangement **404** and the fuel injector **200** are arranged within a common unit, forming a so-called electronic unit injector (EUI). An engine is typically provided with a plurality of EUIs, one for each cylinder. The pumping arrangement **404** is comprised of a pumping chamber **414** and an associated spring-loaded plunger **416** which is operated by a driven cam **418**, such that the plunger **416** is driven back and forth within the pumping chamber **414** whilst the engine is operating. The driven cam **418** has a lobed profile, comprising rising and trailing flanks. When engaged with the rising flank, the plunger **416** is driven into the pumping chamber **414** in a pumping stroke and then recedes, when engaged with the falling flank, during a return stroke. In between strokes, during the remainder of the cam cycle, the plunger **416** is engaged by the substantially cylindrical body portion of the cam and remains substantially retracted with respect to the pumping chamber **414**. When not injecting, the rail control valve **406** is kept in its 'open' position and the movement of the plunger **416** has substantially no effect on the pressure of fuel delivered via the high pressure supply line **208**.

[0009] Details of how the fuel injection system **400** can be used to generate injection events having boot-shaped profiles will now be described. The electronic engine controller commences an injection event by moving the needle control valve **202** into its open position whilst also keeping the rail control valve **406** open. The needle control valve **202** is quickly returned to its closed position, such that the pilot